MARS ORBITER SAMPLE RETURN POWER DESIGN

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Introduction:

Mars has greatly intrigued scientists and the general public for many years because, of all the planets, its environment is most like Earth's. Many scientists believe that Mars once had running water, although surface water is gone today. The planet is very cold with a very thin atmosphere consisting mainly of CO_2 . Mariner 4, 6 and 7 explored the planet in flybys in the 1960s and by the orbiting Mariner 9 in 1971. NASA then mounted the ambitious Viking mission, which launched two orbiters and two landers to the planet in 1975. The landers found ambiguous evidence of life. Mars Pathfinder landed on the planet on July 4, 1997, delivering a mobile robot rover that demonstrated exploration of the local surface environment.. Mars Global Surveyor is creating a highest-resolution map of the planet surface. These prior and current mission to Mars have paved the way for a complex Mars Sample Return mission planned for 2003 and 2005. Returning surface samples form Mars will necessitates retrieval of material from Mars orbit. Sample mass and orbit are restricted to the launch capability of the Mars Ascent Vehicle. A small sample canister having a mass less than 4 kg and diameter of less than 16cm will spend from three to seven in a 600 km orbit waiting for retrieval by second spacecraft consisting of an orbiter equipped with a sample canister retrieval system, and a Earth Entry Vehicle. To allow rapid detection of the on-orbit canister, rendezvous, and collection of the samples, the canister will have a tracking beacon powered by a surface mounted solar array.

The canister must communicate using RF transmission with the recovery vehicle that will be coming in 2006 or 2009 to retrieve the canister. This paper considers the aspect and conclusion that went into the design of the power system that achieves the maximum power with the minimum risk. The power output for the spherical orbiting canister was modeled and plotted in various views of the orbit by the Satellite Orbit Analysis Program (SOAP).

Description:

The spherical orbiting canister has a limited area for power generation, less than 40%, on the surface, due to the restrictions for lid sealing and canister albedo. The solar cells will be arranged in serial circuits and mounted into facets cut into the spherical canister. This was done in order to maximize power generation from each serial circuit at any view angle to the sun. The serial circuits will be diode protected and connected in parallel. The minimum power will be produced when the spherical canister lid is facing the sun and the cells have a 71 degree view of the sun. An additional 20% of the power can also be generated by the cells facing Mars, due to the albedo. The spherical canister will be operating below -26 degrees Celsius and needs to produce a minimum voltage of 3.3 volts. Silicon solar cells were selected as the best option since six silicon triangles would be the best fit onto a circle defined by the facet cut into the spherical surface. Each radiation hardened silicon cell can produce its peak power of .55 volts at -26 degrees Celsius after 10E14 e/cm^2 exposure. Figure 1

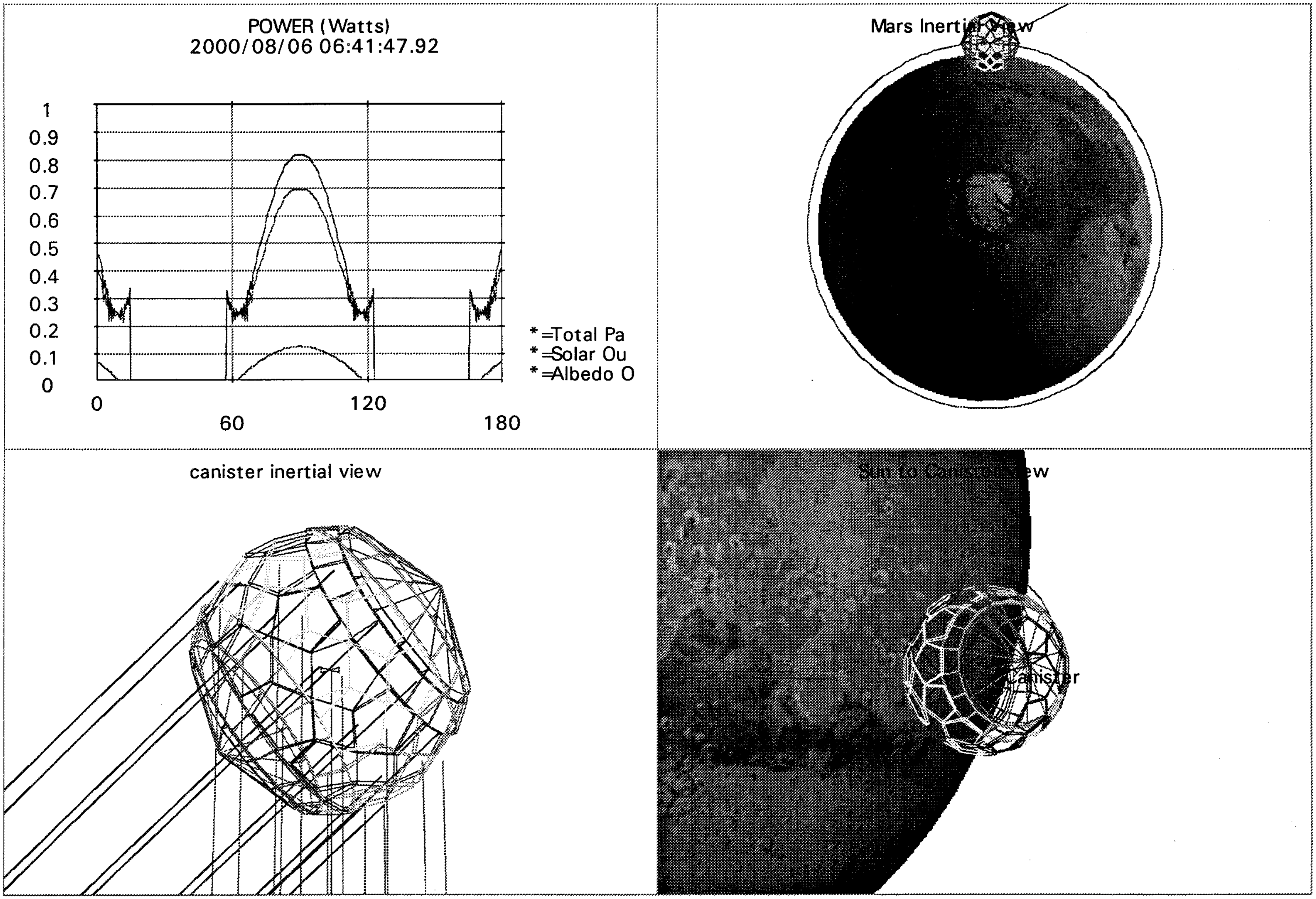

Figure 1. SOAP generated simulation of canister orbiting Mars
Courtesy of Robert Carnright JPL

shows a plot generated by SOAP, of the power produced by the rotating spherical canister as it orbits Mars. The first quad illustrates the power in Watts as it moves in and out of eclipse, second quad illustrates the Mars inertial view of the canister in the 600 km orbit, the third quad illustrates the canisters inertial view indicating the direction of sun and albedo flux, and quad four illustrates the Sun to canister view while in orbit.

The requirements and geometry for a solar array on a sphere are unique and place special constraints on the design. These requirements include 1) accommodating a lid for sample loading into the canister, surface area was restricted from use on the Northern pole of the spherical canister. 2) minimal cell surface coverage (maximum cell efficiency), less than 40%, for the recovery vehicle to locate the canister by optical techniques. 3) a RF tracking beacon which operates during 50% of MARS orbit time on any spin axis, which requires optimum circuit placement of the solar cells onto the spherical canister.

The optimum configuration would have been a 4.5 volt round cell, but in the real world we compromised with six triangular silicon cells connected in series to form a hexagon. These hexagon circuits would be mounted onto a flat facet cut into the spherical canister, Figure 2. The surface flats are required in order to maximize power, the surface of the cells connected in series must be at the same angle relative to the sun. The flat facets intersect each other to allow twelve circuits, evenly spaced just North and twelve circuits South of the equator of the spherical canister. Connecting these circuits in parallel allows sufficient power to operate the transmitter at minimum solar exposure, with the Northern pole of the canister facing the sun. Additional power, as much as 20%, is also generated by the circuits facing MARS due to albedo of MARS.

15.5 cm Diameter Canister

Top side

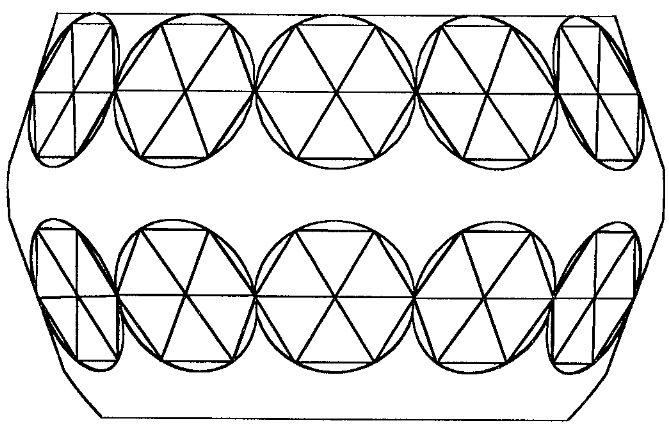

Figure 2

Performance:

It is planned to use thin (50 micron) high efficiency (19%) silicon solar cells with 7.5 micron filters. At Beginning of life (BOL) AM0 28 degree Celsius the six triangular cells connected in series can achieve a maximum power of 244 mW with light normal to the surface, or in orbit about Mars at -26 degree Celsius we expect 117 mW from each circuit. With 12 circuits mounted on each hemisphere we expect an illumination from the sun to be 3.9 to 6.3 circuits which will produce 460 to 737 mW. Additional power of 280 mW also will be generated by the cells facing Mars by the reflection of the Sun off Mars.

The addition of the circuits to the surface of the canister is expected to add less than 120 grams to the weight. The weight is an important factor to consider since this canister must be launched from the surface of Mars and every additional gram of payload requires additional fuel that must be transported to Mars at a high cost.

Summation:

Returning samples from Mars is an ambiguous program for NASA and will add to the exploration and knowledge of our solar system. Teams efforts such as Mars Sample Return are what dreams are made of.